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DESIGN OF AIRSHIP FOR AERIAL SURVEILLANCE AND COMMUNICATION USING KNOWLEDGE BASED ENGINEERING

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ABSTRACT

Design and development of Airships is receiving attention over past 5 years. The present paper deals with the design of an airship that could be hovered for long periods to provide aerial survey and also to act as an intermediate link between two commutation stations operating on low range communication Systems and interruptions in data acquisition.

Existing designs and fabrication techniques were first reviewed. Then, the design was carried out based on the requirements. The emphasis of design was laid on minimum operation and low maintenance cost design. The model was then designed in CATIA and analyzed in ANSYS. The results showed good aerodynamic performance of the airship. The airship prototype was made using 3D printing.

KEYWORDS: Airship, UAV's, Design, Surveillance, Communication & etc

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Original Article

INTRODUCTION

An airship is one type of aircrafts which generally uses a hollow volume filled with gases mostly inert gases. Its ability to be in air is due to the buoyancy force created due to the gases present in these aircrafts. The presence of a low density gas such as H, He, or hot air causes buoyancy force. These are derived from air balloons called as Dirigibles developed by French. Unlike Air balloons, these can be steered and also flown against wind using a propulsive system.

Vehicles such as airships belong to the category of aerostats. The classification of these airships is given below in figure 1.

Types of Airships: These airships can be classified into three types: rigid, semi-rigid and non-rigid. Hot air airships can be counted as a part of the non rigid category. These three classes along with other types of Airships are given in Figure 1

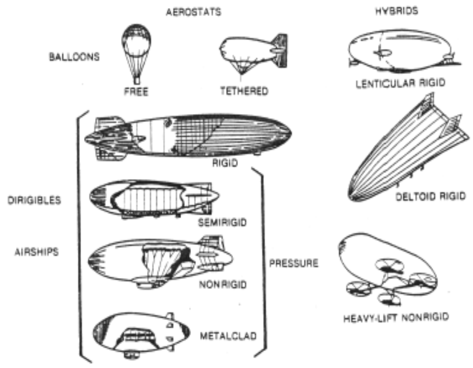

Figure 1: Lighter than Air Aircrafts

Scope of Project: The work described here was directed at investigating new concepts for the design of airship which is capable of withstanding winds for long periods of time.

During this project, the following aspects can be understood

- Design methodology for the airship design
- Various control mechanisms for airship navigation
- Fabrication techniques for the airship

LITERATURE REVIEW

In this a detailed study on airship design, fabrication and applications have been carried out. Due to restricted space, only components are being discussed along with one journal

Components of Airship

The major components of the airship are

- Envelope
- Gondola
- Propeller with Motor
- Camera with Transmitter
- Battery
- Empennage or Tail

In 1980, Durney outlined the causes of local failure in large aerostat envelopes. He devised a means of preventing the propagation of local failures into catastrophic failures by installing a network of high-strength rip-stop material, thereby reducing damages and repair costs, but did not look into preventing local failures in the first place.

Other studies directed at improving the robustness of free balloons, such as research on natural, “pumpkin” shapes to enhance the capabilities of stratospheric and super pressure balloons, have not yet produced findings that lend themselves to mitigating failures due to concentrated loads in tethered aerostats.

PROPOSED METHODOLOGY

Any Design process is always driven by a set of the requirements which are provided by the user of the company. Based on these requirements, the design of airships is started. Initially, all the required dimensions of the airships have been calculated and later the aerodynamic characteristics of the design are evaluated in FLUENT. This will end of the conceptual phase, where the layout of the design is completed.

Based on the Aerodynamics Data obtained, the preliminary design begins and the flight control and propulsive systems required to derive the airship are estimated.

Weight Estimation

At the initial stage, we assume arbitrary values of the mass of the systems based on which the net buoyancy lift required is calculated. The preliminary weight of the airship can be estimated is given in table

Lift and Buoyancy

An airship may obtain lifting from three primary sources. They are static lift, Dynamic Lift and Powered Lift. The static lift is generated by the buoyancy force of gases which cause the displacement of the body. For airships, this is the balloon.

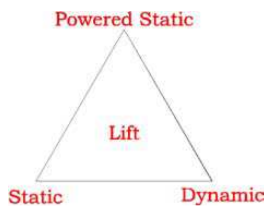

Figure 2: Lifting Force

The lifting force depends on the gas being used in the hull. For this a study of the different gases has been made which are tabulated below.

Table 1: Gases and their Properties

Gas	Density	Lifting Force	Comment
Hydrogen	0.085 kg/m^3	11.2 N/m^3	Inflammable, relatively cheap
Helium	0.169 kg/m^3	10.2 N/m^3	Inert, relatively expensive
Hot Air	0.906 kg/m^3	3.14 N/m^3	Inert, very cheap, relatively poor lift
Methane	0.756 kg/m^3	4.5 N/m^3	Inflammable, relatively cheap

Helium can be considered best among these due to the availability and inflammability. Commercially, Helium is available at greater than 98 percent purity. This means that the lifting force of Helium depends on its purity and is never 100 percent.

Static Lift of an Airship

$$F_{lift} = (\rho_{air} - \rho_{gas}) g V$$

Where, V is Volume of the gas

Here, Volume of the airship can be calculated based on the above equation as Lift is equal to the total weight of

the aircraft.

$$1.89 = (1.225- 0.169)\ V$$

V= 1.79 m^3

Calculation of Surface Area and Projected Area

Based on the above discussion, it is important to have a better understanding of the size and shape of the envelop. The Shape of the envelop is direct indication of the drag produced by the design. So, it is important that a compromise must be made while designing envelop for airships. Based on the historical trends, a Fineness ratio (Length to Diameter ratio) of 2.27 is considered for the design

Envelop Dimensions

$$V_1 + V_2 = V_T$$

$$\frac{4}{6}\pi a_1 b^2 + \frac{4}{6}\pi a_2 b^2 = 1.89$$

$$\frac{4}{6}\pi b^2(a_1 + a_2) = 1.89$$

But, $a_1 + a_2 = l; \frac{l}{b} = 2.27$

$$\frac{4}{6}\pi b^3(l/b) = 1.89$$

$$\frac{2}{3}\pi b^3(2.27) = 1.89$$

$b = 0.375$ m

$l = 1.702$ m

$a_1 = 0.7$ m

$a_2 = 1$ m

$$S = 2\pi\left(\frac{2(ab)^{1.6}+b^{3.2}}{3}\right)^{\frac{1}{1.6}}$$

$S_1 = 3.38\ m^2$

$S_2 = 4.32\ m^2$

Layout of Airship

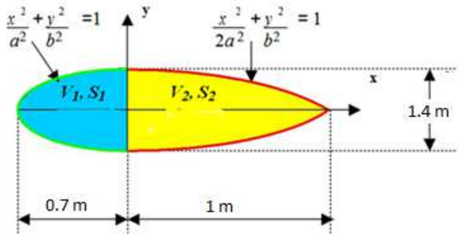

Figure 3: Airship Dimensions

DRAG CALCULATION

Shape of the airship plays a major role in reduction of drag as rag is function of the total surface area. This shape effect can be understood by term *Shape coefficients*.

Pressure Drag: The relation between shape and the Pressure is given by

$$R_p = K_\infty S V^2$$

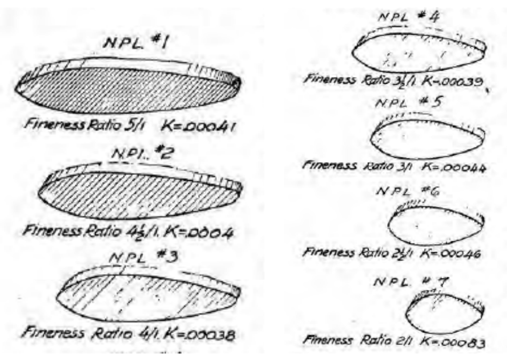

Figure 4: Fineness Ratio and K

For Fineness Ratio of 2.27 to 2.5, K = 0.00046

Skin Friction Drag: The value of the skin friction on an airship hull, as determined empirically by Zahm and others, is given by the formula

$$R_s = 0.0035\, \rho\, S^{0.93} v^{1.86}$$

Where 'S' is the total surface area. A somewhat more convenient formula

$$R_s = 0.0035\, \rho S v^{1.85}$$

Since airship operates at low speeds, the maximum velocity is considered as 2 m/s. However, the operating velocity is 1 m/s. using the above relation the drag can be plotted at various velocities.

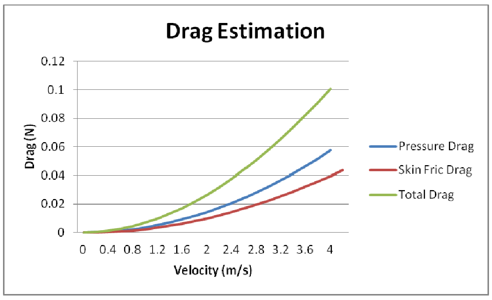

Figure 5: Drag Variations with Velocity of Airship

THRUST REQUIRED

We are using two motors, one on each side that can tilt up or down. These motors are used for controlling the motions such as the pitching, forward and reverse motions of the airship. The thrust required is evaluated based on the drag. At steady level flight, Drag is equal to Thrust. Hence, Thrust required is function of drag and varies with velocity of airship.

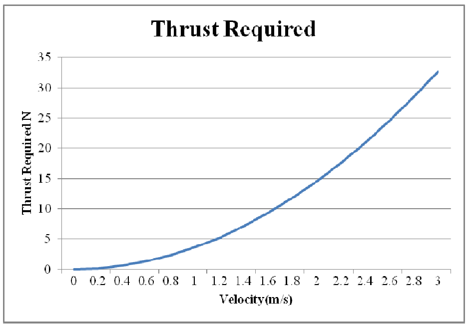

Figure 6: Thrust Required Graph

Motor Selection

As we are using two motors to drive the system, each system must be capable of providing a thrust which is half of the required thrust. So, Two 'Turnigy 4240 Brushless Motor 1300kv' are selected, to drive the airship. The specifications are given below

Table 2: Motor Specifications

S No	Particular	Magnitude
1.	v(rpm/v)	1300
2.	Weight (g)	134
3.	Max Current(A)	60
4.	Max Voltage(V)	15

EMPENAGE

To calculate dimensions of the tail section, the statistical data has been collected and tabulated below

Table 3: Parameters Derived from Statistical Data

S. NO	Parameter	Value
1	Tail area ratio	0.061
2	Fin location ratio	0.907
3	Fin taper ratio	0.596
4	Fin aspect ratio	0.702

5	Control area ratio	0.258
6	Control taper ratio	0.258

Based on the data given in table, the following dimension are obtained for tail

Table 4: Tail Dimensions Obtained

S. NO	PARAMETER	Magnitude	Units
1	Tail Area	0.118	m^2
2	Fin Area	0.087	m^2
3	Control Surface Area	0.030444	m^2
4	Fin Span	0.266526	m
5	Root Chord	0.554804	m
6	Tip Chord	0.330663	m
7	Control Surface Root Chord	0.122297	m
8	Control Surface Tip Chord	0.106154	m

FINAL LAYOUT

The design has been generated in CATIA V5 as per the specification and dimensions obtained from the performed calculation. The design obtained is given in figure 7 below

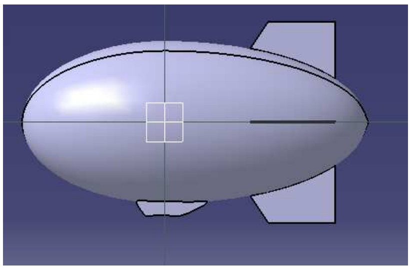

Figure 7: Final Lay Out

ANALYSIS

Analysis to evaluate drag and Pressure distribution over airship was carried out in ANSYS Fluent. The result has been analyzed in selection of material. The pressure distribution over the airship is obtained and a contour is generated as shown in Figure 8

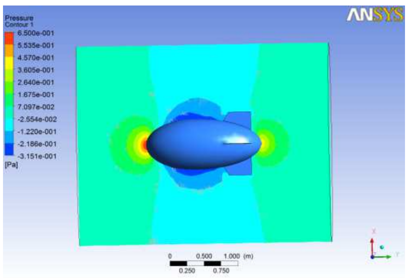

Figure 8: Pressure Contour

RESULTS AND DISCUSSIONS

Drag: The drag obtained from the fluent analysis was 8N which is less than the evaluated drag for the airship. So, the design can be utilized for further optimization

Material Selection: Smaller aerostats, such as those considered here, tend to employ ultra-light materials that

consist of only a load-bearing base with a linen binding and rip-stop thread, and an applied coating or film as the gas barrier. Polyesters such as Dacron, polyamides such as nylon, and polyurethane are the most suitable base fabrics because of their high strength-to-weight ratios, and ease of manipulation, bonding, and construction. Common gas barrier components include neoprene, polyurethane, and polyvinyl fluoride.

Based on this, the 4.2 oz/yd^2 (98 g/m^2) single-coated "***Heat-Sealable 70 Denier Urethane-Coated Nylon Taffeta***" was selected, as it was the lightest material available that could be easily manipulated while also meeting the design requirements with respect to break strength.

Table 5: Refined Weight Estimation

Components	Estimated Weight (g)	Weight Obtained (g)
Motors	185	220
6-9 propellers	45	40
Motor holders	60	0
Servo	20	75
Micro Receiver	20	40
Battery (NiCd 4.8V)	250	200
ESC with Switch	20	20
Video Camera with Transmitter	150	150
Battery11V	60	60
Tail	40	40
Gondola	50	50
Envelop	990	756
Total	1890	1645

CONCLUSIONS

The objectives of this project have been met. An UAV is designed with the intention of operating for the surveillance. The computational analysis has shown that the airship designed has a good aerodynamic performance than analytically calculated.

The maximum thrust of 20N can be generated which can drive the airship at a cruise speed of 2 m/s. With the operation of the tail fin, it gives a better stability. The performance is suitable for slow speed operation required for surveillance. However, the weather can have adverse effect on the performance of the airships. Hence, there shall be an aid that has to be carried out during the operation. The drag on the airship is high when exposed to heavy winds.

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